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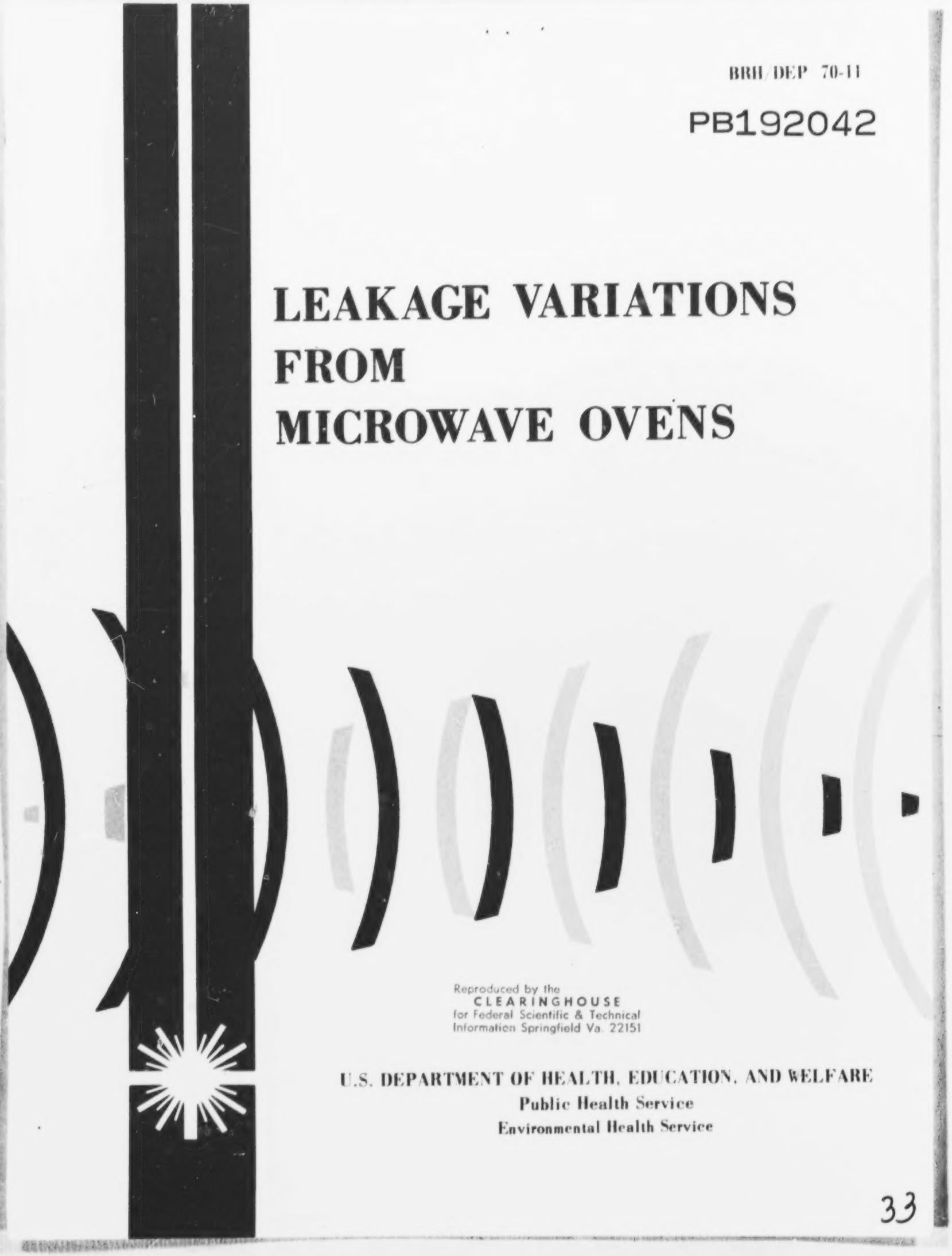
LEAKAGE VARIATIONS FROM MICROWAVE OVENS



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DIVISION OF ELECTRONIC PRODUCTS

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LEAKAGE VARIATIONS FROM MICROWAVE OVENS

Product Testing and Evaluation Branch
Division of Electronic Products

June 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Radiological Health
Rockville, Maryland 20852

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FOREWORD

The Bureau of Radiological Health, formerly the National Center for Radiological Health, continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), Public Health Service numbered reports, appropriate scientific journals, and technical report series for the Bureau's divisions, offices, and laboratories.

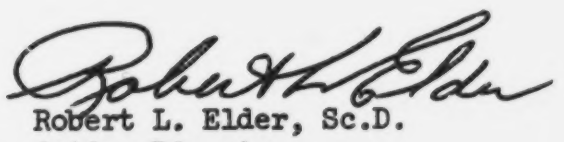
The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

Some microwave radiation leakage is generally associated with the operation of microwave ovens. This leakage, which usually occurs around the door seals, will vary depending on the type, size, and placement of food or other load within the oven cavity. This report describes field and laboratory studies that were performed to determine the most important variables and their effect on microwave oven radiation leakage levels. Many individuals and agencies have contributed to the data that are presented and to the preparation and review of the material. While it is impossible to enumerate all of these contributors, their assistance is sincerely appreciated.



Robert L. Elder, Sc.D.
Acting Director
Division of Electronic Products

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ABSTRACT

Some microwave radiation leakage is generally associated with the operation of microwave ovens. This leakage usually occurs around the door seals and varies with the type, size, and placement of food or other loads within the oven cavity. This report describes field and laboratory studies that were performed to determine the most important variables and their effect on microwave oven radiation leakage levels. Additional field observations of ovens in use should be conducted to more clearly define the correlation between food types, sizes, and placement, and door closing and opening procedures.

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LEAKAGE VARIATIONS FROM MICROWAVE OVENS

INTRODUCTION

The objective of the studies described herein was to determine the most important variables that must be considered in any test procedure used to measure microwave radiation leakage from microwave ovens. The results of this work will be of value in determining uniform microwave test procedures for future activities under the Radiation Control for Health and Safety Act of 1968, Public Law 90-602. A commonly used test procedure involves placing a 275-ml water load in the center of the oven and measuring the microwave radiation leakage as the door is being opened. The procedures and instrumentation used in these studies are described in appendix A.

FIELD-USE STUDY

Four microwave ovens selected from a list of approximately 200 ovens were observed in use in public vending establishments and dining rooms. For each oven, the observed leakage varied considerably from one operation to the next (see table 1, appendix B). Many different sizes, shapes, and types of food were observed being heated. The placement of the food in relation to the center of the cooking cavity was also observed and was found to vary significantly. The microwave leakage varied with the use for one oven by as much as 23 to 1, for a second by 9 to 1, for a third by 5.5 to 1, and for the fourth by 1.3 to 1.

Using the same four ovens, the leakage was measured with two small food loads placed individually in five different positions in each of the ovens and compared with the leakage measured for a water load of 275 ml in the same five positions (see table 2, appendix B).[1] In most cases greater leakage was observed for smaller portions of food than for the 275-ml water load placed in the center. In addition, some of the ovens showed variations in leakage of as much as 6 to 1 for five positions of both food and water load placement. Again, with the same four ovens, seven different volumes of water loads ranging from 50 to 500 ml were tested in five positions as described in appendix A. The data from these tests are presented in table 3, appendix B. For the Raytheon Mark VI there seemed to be no real variation in leakage with

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[1]All water loads were in a low-form 600-ml Pyrex beaker.

load volume or position within the oven. For a Litton 500 there was a slight indication that the smaller volumes of water were associated with higher levels of leakage and that use of the center position resulted in greater leakage than did the other positions. For the Raytheon Mark V there was again an indication that the smaller volumes of water were associated with higher levels of leakage but that changes in load position did not seem critical. For another Litton 500 there was some indication that the lighter loads produced more leakage and that the center position seemed to be associated with the greatest leakage.

The results of these field studies indicated that different volumes of water loads seemed to produce leakage results comparable to that resulting from tests with food loads of similar size and that the positioning of the food seemed to create significant variations in leakage from some ovens. The center position most often was associated with the greatest microwave leakage, as were the smallest loads.

COMPARATIVE FIELD MEASUREMENTS

In cooperation with a State health department, microwave oven radiation leakage measurements were performed on more than 60 ovens. The leakage was measured first with a 275-ml volume of water centered in the cooking cavity. The leakage was then measured with 50 ml of water centered in the cavity and then with the same 50-ml water load placed in each of the four off-center positions. The results of these tests are tabulated in table 4, appendix C. When the leakage using 50 ml of water in the center of the oven was compared with that using 275-ml in the center, the results were greater with 50 ml of water in 41 out of 63 cases; in 13 cases they were identical; and in 9 cases they were less.

These findings indicate that a small volume of water, such as 50 ml, will produce more leakage than will 275 ml of water in at least the majority of ovens of the types tested during this survey. Also, the data in the aggregate show little reason to choose one load position over another.

LABORATORY MEASUREMENTS

Laboratory tests were performed to complement the observations made in the field studies and to extend these studies to the use of oven types that might be found in homes as well as in food preparation and vending establishments.

Three ovens, two of which were designed for use in the home, were tested for variations in leakage with changes in load volumes and placement. The results are presented in table 5, appendix D. No attempt was made to alter the factory adjustments of the features intended to control microwave leakage. The General Electric Versatronic® oven, a home oven, rotated the load. With the water load placed in the center of the rotisserie and with large volumes of water (200-500 ml) the recorded leakage was lowest, but with small volumes of water (less than 200 ml) the recorded leakage was greater. With the water loads placed progressively farther from the center of the rotisserie, the size of the water load became a less significant factor, but the leakage, averaged over the total variations in water volumes tested, became greater. This may be due to the manner in which the readings were recorded, since the maximum transient reading of the meter was recorded as the value of the leakage. As the load rotated in the oven, there was an observed peak in the reading which occurred at the same frequency as the rate of rotation of the load -- about once every eight seconds.

When the Magic Chef®, also a home oven, was tested with water of different volumes in the laboratory, the leakage appeared to be independent of water load placement but became progressively higher with smaller volumes of water.

The Garland oven, when tested with loads of various volumes and placements, gave much more variable results. In general, leakage was greater when smaller water volumes were used. The most leakage occurred when the load was placed in the center. Variations in load placement seemed to have little effect.

In order to further evaluate in the laboratory the variation in leakage at magnitudes approaching those found in the field, leakages of approximately 10 mW/cm^2 were deliberately produced in six ovens using a 275-ml water load in the center of each oven. The leaks were formed by using strips of nonconductive nylon filament tape placed on the door frames to interrupt the door seals. Layers of tape were then added until leaks near 10 mW/cm^2 were measured at 5 cm from the door edges. The tape remained on the door frames during tests of different water load volumes and placements. The results of these tests are shown in table 6, appendix D.

The General Electric oven with the deliberately-produced leak exhibited levels greater in magnitude than those observed from the unaltered oven, but showed essentially the same patterns. This is shown in figure 1. Because this oven operates at a different microwave frequency than the others and uses a rotisserie for rotating food, the microwave radiation leakage measurement problem is unique, and all water loads produce a greater recorded leakage when placed near the edge of the rotisserie than when placed in the center. The variations in measurements of leakage from the General Electric oven will be illustrated and discussed in a separate Division of Electronic Products report, "The Effect of Instrument Averaging Time on Microwave Power Density Measurements."

The Magic Chef oven with a deliberately-produced leak, when tested with water loads of different volumes, gave leakage measurements that appeared to be independent of water load placement, but that become progressively greater with smaller volumes of water (see figure 2). These results, except for magnitude, are the same as those found when the door seal was intact.

The Garland oven with a deliberately-produced leak, when tested with water loads of different volumes placed in different positions, gave leakage measurements that were larger when smaller volumes of water were used and did not seem to depend critically on load placement.

The Amana RR-2 oven with a deliberately-produced leak, when tested with water loads of different volumes placed in different positions, gave leakage measurements that were slightly greater for smaller water volumes and were significantly larger when the smaller water loads were placed in the center position.

The Omnivend oven with a deliberately-produced leak, when tested with water loads of different volumes placed in different positions, gave leakage measurements that were also generally greater when smaller water volumes were used. These results did not seem to depend critically upon load placement.

The Litton 800 oven with a deliberately-produced leak, when tested with water loads of different volumes placed in different positions, gave leakage measurements that showed little dependence on either water load volume or placement.

With the deliberately-produced leakage condition still in effect, six different foods were placed one at a time in each of the test positions in each of the six ovens. The results are presented in table 7, appendix D. Except for the General Electric oven, there seems to be a strong correlation between the water load tests and the tests with various sizes, types and positions of foods.

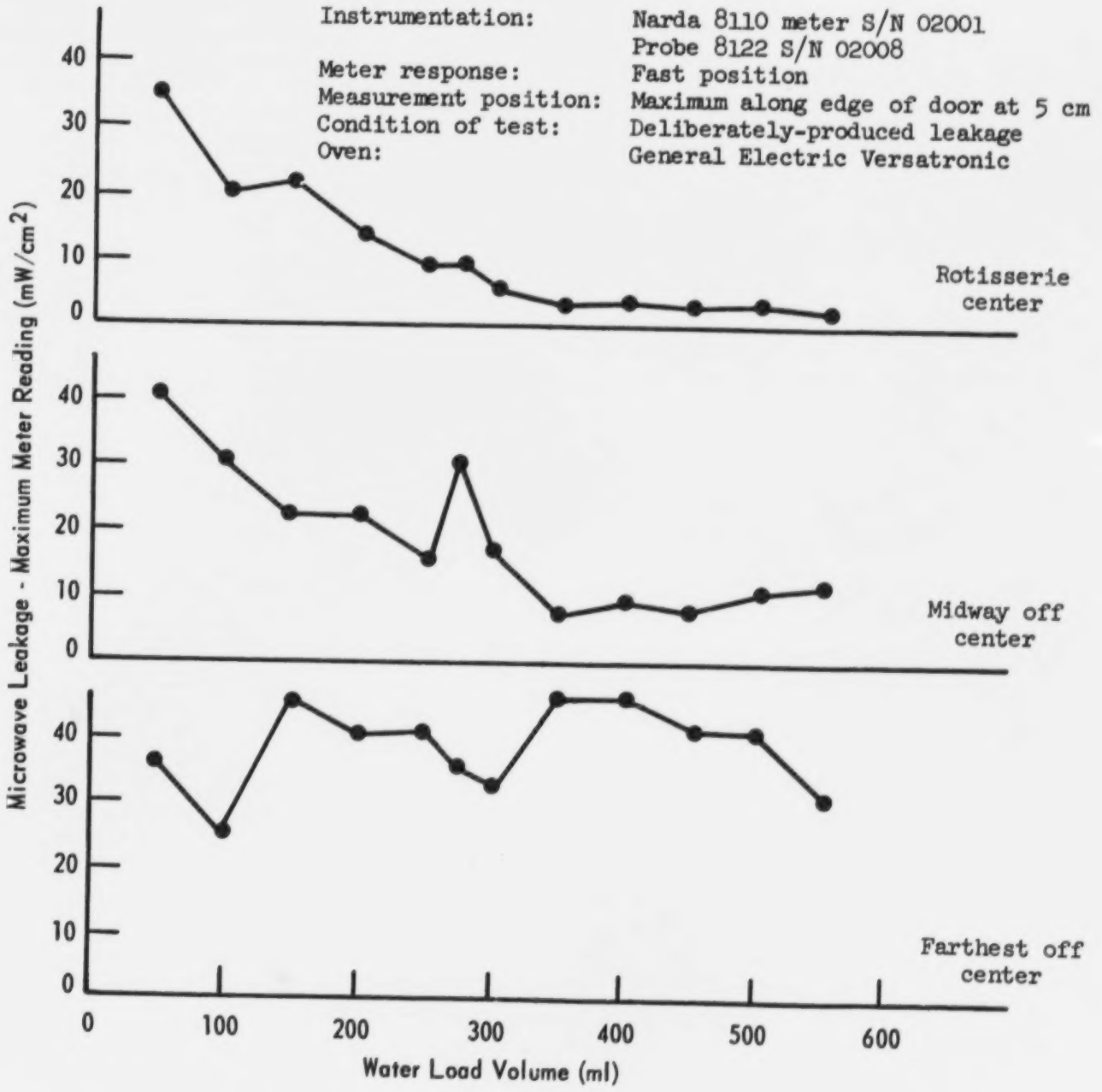

Figure 1. Leakage power density as a function of water load volume and placement with a deliberately-produced leak (General Electric oven).

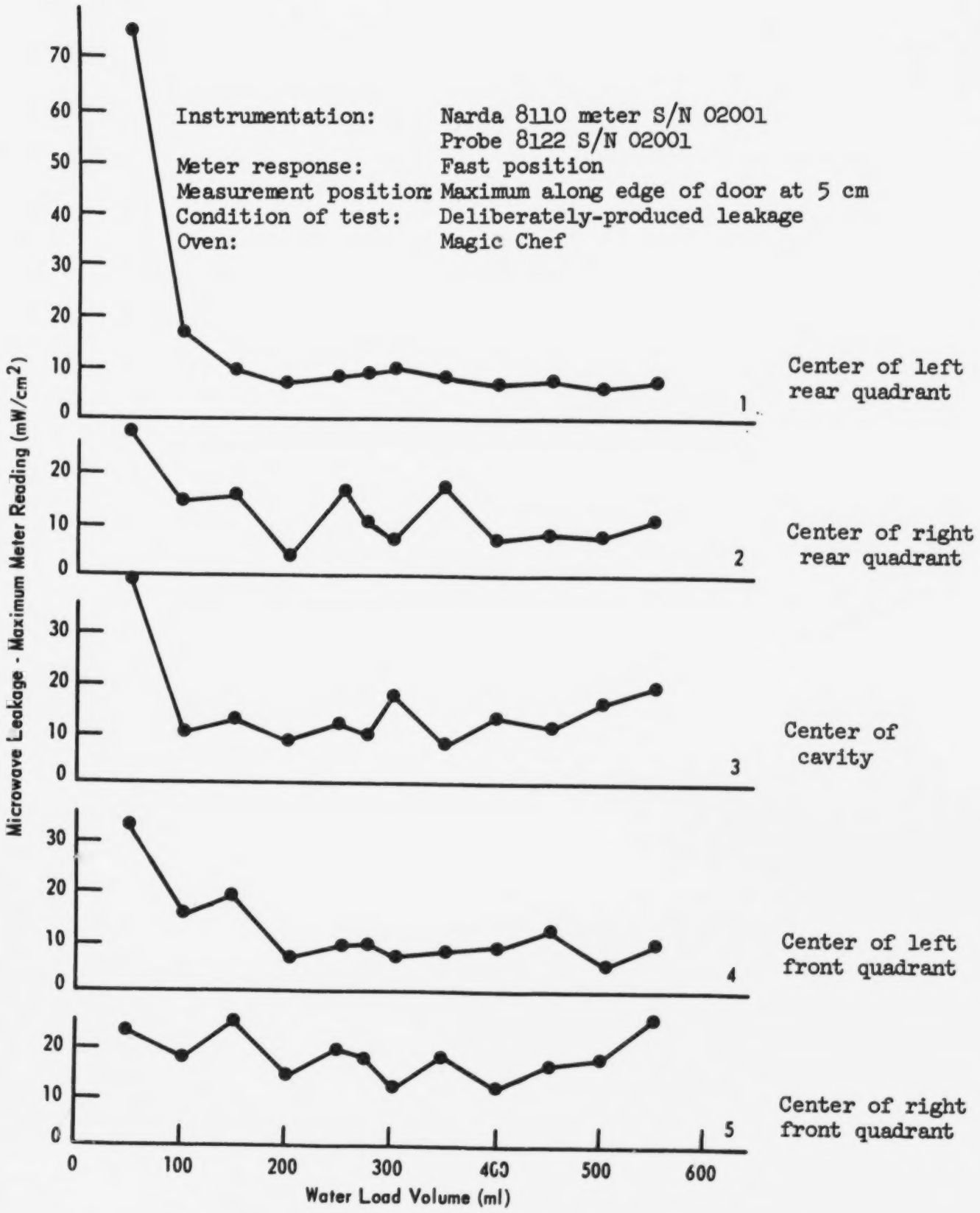

Figure 2. Leakage power density as a function of water load volume and placement with a deliberately-produced leak (Magic Chef oven).

MISCELLANEOUS TESTS

The Underwriters' Laboratories has suggested that corn oil be used instead of water as a test load. The procedures for varying load placement as described in appendix A were used for two ovens with 275 ml of water and with 275 ml of corn oil in the same types of container. In both ovens, when the load was placed in the center of the cavity, the measured leakage was slightly greater for the water than it was for the corn oil. When the load was placed in any of the other four off-center positions, the corn oil gave greater leakage measurements. The results are illustrated graphically in figure 5, appendix E. There did not appear to be a direct relationship between leakages resulting from these two types of loads. Without further studies, there seems to be no technical basis for considering one type of load as superior to the other.

The results of the tests described earlier in this report indicate that the same microwave leakage patterns are observed as the load volume and position are changed, regardless of the magnitude of the measured radiation leakage. Some of the ovens tested had safety interlocks whose operation depended on the motion of the oven door. Therefore, the oven could remain in full operation when the door was partially open and the motion of the door had changed the microwave leakage control capability of the door seal. In most cases this resulted in an increase in the measured radiation leakage as the door was opened until the point was reached where the first safety interlock operated. The Tappan model R4A microwave oven was chosen to determine the possible ranges of increase in leakage, because the single safety interlock which operated from the door motion could be adjusted over a range of door movements. Table 8, appendix E lists the results of these measurements. The data presented are for three different adjustments of the single interlock mechanism and indicate that considerable care needs to be taken when adjusting this safety interlock. No adjustment reduced the measured power density leakage below 75 mW/cm^2.

CONCLUSIONS

The conclusions that can be drawn from these laboratory and field studies are as follows:

(a) Microwave leakage from ovens observed in use with many different sizes, shapes and types of food, varied by as much as 23 to 1 for one oven, 9 to 1 for another, 5.5 to 1 for a third, and 1.3 to 1 for a fourth oven. Additional field observations of ovens in use must be conducted to more clearly define the correlations between microwave radiation leakage and food types, sizes and placement, and door closing and opening procedures.

(b) Different volumes of water loads seemed to produce leakage results comparable to those resulting from tests with food loads of similar size.

(c) In most cases a small volume of water such as 50 ml will produce a leakage at least twice that of a 275-ml water load. The field data show little reason to choose one load position over another. Thus, a smaller load, such as 50 or 100 ml of water, placed in the center of an oven is an acceptable test condition which may be more comparable to a light load during actual use. Such a load is also an acceptable field test condition for compliance activities under P.L. 90-602.

(d) Because of the variability of microwave leakage from oven to oven and with different load volumes and positions, the microwave oven manufacturers should not confine their testing program to a single test condition but should test their ovens with different loads placed in different locations.

(e) The same microwave leakage patterns were observed as the load volume and position were changed, regardless of the magnitude of the radiation leakage that was measured.

(f) From the limited laboratory tests performed, there appears to be no distinct advantage for choosing corn oil as a test load, particularly in view of its disadvantages for field use.

(g) For those microwave ovens in which the safety interlocks are adjustable and operate from the motion of the door, considerable care must be taken when adjusting these safety interlocks, and further tests should be performed to measure microwave leakage under such conditions.

APPENDIX A

PROCEDURES AND INSTRUMENTATION

All measurements were made with a Narda model 8100 survey instrument. The model numbers and ranges of the associated survey probes are as follows:

Narda survey meter - Model 8110

Narda probe - Model 8120 - 0 to 0.2 mW/cm^2
0 to 2.0 mW/cm^2

Narda probe - Model 8121 - 0 to 2.0 mW/cm^2
0 to 20 mW/cm^2

Narda probe - Model 8122 - 0 to 20 mW/cm^2
0 to 200 mW/cm^2

The measurements were taken at a distance of 5 cm unless otherwise noted, and at all times the fast response of the instrument was used and the maximum meter reading was recorded.

The loads were placed in the ovens in five different positions. One oven design was such that only three positions were used. These positions for each case are indicated in figure 3 below:

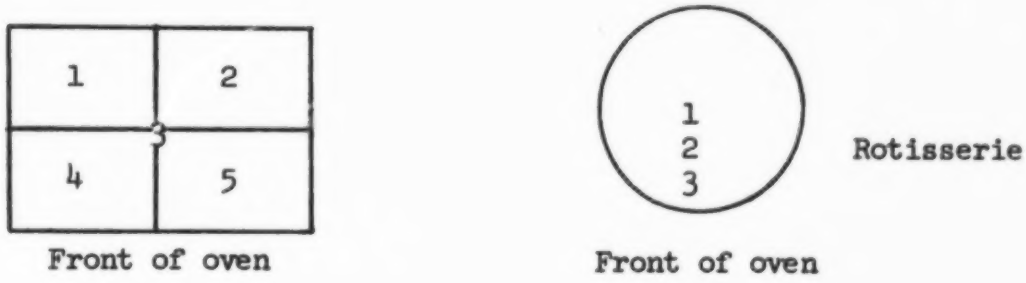

Figure 3. Load placement key - plan view of cavity floor.

When performing the tests involving liquid loads (water and corn oil), once the beaker was initially placed in one of the indicated positions, it was not disturbed until that series of tests at that position was complete. All water was added while the beaker remained in the oven.

For the field-use study the following coded figures were used to record the locations of microwave leakage from the front of the oven.

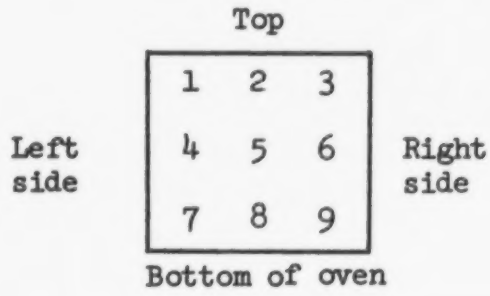

Figure 4. Key to location of microwave leakage for field-use study (see table 1, appendix B).

The period of testing during the field-use study was usually two hours long during the high-use time of operation, which was generally during the lunch hour.

The microwave ovens tested in the laboratory were of the following makes and models:

General Electric Versatronic Model P7, Serial No. DEE00056

Magic Chef Model MC 75.01, Serial No. 1674

Welbilt-Garland Model EM-1, Serial No. 133308

Amana Model RR-2, Serial No. S18357883

Omnivend Model 110D, Serial No. 2125

Litton Model 800, Serial No. 1319

APPENDIX B

DATA FROM FIELD USE STUDY

Table 1. Data from field study during normal use of microwave ovens

Food item	Placement of load[a]	Leakage level (mW/cm^2)	Location of leakage[b]	Cooking time (seconds)	Position of operator
Raytheon J1015 Mark VI Test No. D.C. 1					
Thawed steak	3	2.5	9	200	10 ft. from oven
Beef burgundy dinner	2	2.5	2	403	6-10 ft. from oven
Beef burgundy dinner	2	2.5	4	393	6-10 ft. from oven
Beef burgundy dinner	1	3.3	2	413	6-10 ft. from oven
Litton 500 S/N 18859 Test No. D.C. 2					
Cheeseburger	3	1.5	2	35	2 ft. to side
Hot dog	1	1.5	8	27	2½ ft. front
Ham and cheese	3	1.2	8	39	2 ft. side
Cheese	3	1.2	8	36	Operator not present
Sandwich and pastry	3	0.4	2	28	2 ft. side
Sandwich	5	1.0	2	14	2 ft. side
Soup	3	1.2	2	72	3 ft. front
Pizza	3	2.5	8	39	1 ft. side
Cheeseburger	2	1.2	8	36	2 ft. side
Hamburger	3	0.7	8	26	1 ft. front
Ham and egg sandwich	3	0.8	8	26	1 ft. front
Hot dog	3	2.0	8	27	1 ft. front
Steak sandwich	3	0.9	2	37	1 ft. side
Hot dog	3	2.5	8	36	2 ft. front
Ham and cheese	3	0.8	8	38	1 ft. side
Cheeseburger	4	0.7	8	46	4 ft. side

[a]Refer to appendix A, figure 3.
[b]Refer to appendix A, figure 4.

Table 1. Data from field study during normal use of microwave ovens (continued)

Food item	Placement of load[a]	Leakage level (mW/cm^2)	Location of leakage[b]	Cooking time (seconds)	Position of operato
Litton 500 S/N 18859 Test No. D.C. 2 (cont'd.)					
Chicken sandwich	3	0.7	8	20	2 ft. front
Roast beef sandwich	3	0.4	8	27	1 ft. front
Soup	1	3.0	5	80	2 ft. side
Hamburger	3	1.2	8	32	2 ft. side
Barbecue sandwich	3	1.5	8	42	2 ft. side
Ham and cheese	3	1.9	5	47	1 ft. front
Cheeseburger	3	1.9	8	36	1 ft. side
Ham and cheese	4	0.7	8	26	1 ft. side
Ham and cheese	4	1.5	8	72	1 ft. side
Bologna	3	0.7	5	36	1 ft. side
Hoagie	4	1.0	8	27	1 ft. front
Hot dog	3	1.8	5	27	1 ft. side
Ham and cheese	3	1.0	5	26	2 ft. side
Cheeseburger	3	1.3	5	37	1 ft. front
Cheeseburger	3	1.0	5	37	1 ft. front
Corned beef	1	1.2	8	31	2 ft. front
Pastry	3	3.0	8	11	2 ft. side
Barbecue sandwich	1	1.7	5	38	1 ft. side
Pastry	3	3.5	8	27	1 ft. side
Ham and cheese	3	1.1	8	35	2 ft. front
Raytheon Mark V Test No. D.C. 3					
One 8-oz. glass of water always in oven during operation	4	50	1		
Heat pastrami	3	50	1	26	2 ft. front
Thawed steak	3	52	1	20	2 ft. front

[a]Refer to appendix A, figure 3.
[b]Refer to appendix A, figure 4.

Table 1. Data from field study during normal use of microwave ovens (continued)

Food item	Placement of load[a]	Leakage level (mW/cm^2)	Location of leakage[b]	Cooking time (seconds)	Position of operator
Raytheon Mark V Test No. D.C. 3 (cont'd.)					
6 pie slices on a tray	3	10.0	1	50	2 ft. front
3 pie slices on a tray	3	35	1	40	2 ft. front
Thawed fish	3	32	1	27	2 ft. away from oven
Heat hamburger	3	45	1	27	3 ft. away from oven
Heat hamburger	3	40	1	18	3 ft. away from oven
Heat hamburger	3	40	1	15	3 ft. away from oven
Corned beef	3	45	1	20	3 ft. away from oven
Hamburger	3	35	1	15	3 ft. away from oven
Pastrami	3	35	1	20	3 ft. away from oven
Pastrami	3	55	1	18	3 ft. away from oven
Pie	3	50	1	20	3 ft. away from oven
Litton 500 Test No. D.C. 4					
Barbecue sandwich	3	7.5	9	28	1 ft. front
Soup	3	25	9	87	1 ft. front
Soup	3	60	9	80	1 ft. front
Hot dog	3	12.0	9	28	1 ft. front
Hamburger	3	12.0	9	39	1 ft. front
Hamburger	3	10.0	9	45	1 ft. front
Soup	3	70[c]	9	77	1 ft. front
Soup	3	7.5	9	78	1 ft. front
Beef casserole	3	11.0	9	135	1 ft. front
Chile	4	3.5	7	62	1 ft. front
Hot dog	3	11.0	9	28	1 ft. front
Hot dog	3	20	9	29	1 ft. front
Sausage & eggs sandwich	3	6.0	9	54	1 ft. front
Sausage sandwich	4	6.5	9	38	1 ft. front
Barbecue sandwich	3	6.0	9	26	1 ft. front

[a]Refer to appendix A, figure 3.
[b]Refer to appendix A, figure 4.
[c]At one foot from the door, a power density level of approximately 5 mW/cm^2 was measured.

Table 1. Data from field study during normal use of microwave ovens (continued)

Food item	Placement of load[a]	Leakage level (mW/cm^2)	Location of leakage[b]	Cooking time (seconds)	Position of operator
Litton 500 Test No. D.C. 4 (cont'd.)					
Hoagie	3	10.0	9	78	1 ft. front
Casserole	3	11.0	9	60	1 ft. front
Casserole	3	5.0	9	60	1 ft. away
Hamburger	3	3.0	9	38	1 ft. away
Hamburger	3	11.0	9	39	1 ft. away
Hamburger	3	6.0	9	38	1 ft. away
Soup	3	25	9	84	1 ft. away
Soup	3	28	9	77	1 ft. away
Hamburger	3	9.0	9	47	1 ft. away
Hamburger	3	4.0	9	37	1 ft. away
Spaghetti	3	15.0	9	47	1 ft. away
Soup	3	27	9	80	1 ft. away
Soup	3	17.0	9	70	1 ft. away
Soup	3	35	9	82	1 ft. away

[a]Refer to appendix A, figure 3.
[b]Refer to appendix A, figure 4.

Oven	Position[a]	Microwave leakage (mW/cm^2)		
		275-ml Water load	Fishcake (58g)	Caramel roll (30g)
Raytheon Mark VI D.C.-1	1	1.5	2.5	3.5
	2	2.2	1.5	3.5
	3	2.0	4.5	6.0
	4	3.0	2.5	3.5
	5	2.5	3.0	5.0
Litton 500 D.C.-2	1	3.5	4.5	5.5
	2	1.0	3.0	4.0
	3	7.0	5.0	3.5
	4	0.5	3.5	2.5
	5	1.0	4.0	2.5
Raytheon Mark V D.C.-3	1	200	180	>200
	2	180	130	70
	3	150-180	159	>200
	4	90	190	190
	5	145	>200	190
Litton 500 D.C.-4	1	10.5	35.0	45.0
	2	16.0	11.0	15.0
	3	25	40.0	40.0
	4	4.0	6.5	11.0
	5	3.5	6.0	35.0

[a]Refer to appendix A, figure 3.

Table 3. Microwave leakage in mW/cm^2 with different volumes of water in five positions within four microwave ovens

Oven	Position of load[a]	Water load volume (ml)						
		50	100	200	275	300	400	500
Raytheon Mark VI	1	5.0	1.0	1.5	1.5	2.0	3.5	2.5
	2	3.5	4.0	2.5	2.2	1.5	4.5	2.5
	3	4.0	2.0	2.0	2.0	2.0	2.0	2.0
	4	4.5	5.0	3.5	3.0	3.0	2.5	1.5
	5	3.5	3.5	3.5	2.5	2.5	2.0	2.0
Litton 500	1	5.0	2.5	3.5	3.5	2.5	2.5	3.0
	2	1.5	2.0	1.5	1.0	1.0	1.0	1.0
	3	15.0	15.0	7.5	7.0	6.0	8.5	3.5
	4	1.5	2.0	1.0	0.5	0.5	0.5	2.0
	5	7.0	5.5	3.0	1.0	1.0	1.0	0.5
Raytheon Mark V	1	200	200	200	200	170	140	140
	2	200	200	200	180	130	130	135
	3	160	160	200	180	170	110	120
	4	160	180	120	90	90	90	95
	5	200	200	135	145	190	160	90
Litton 500	1	10.5	14.0	5.0	10.5	9.5	13.0	17.5
	2	18.0	11.5	8.5	16.0	10.5	8.0	2.5
	3	25	15.0	25	25	16.0	10.0	7.0
	4	8.0	2.0	8.0	4.0	5.0	5.0	7.0
	5	4.5	25	6.0	3.5	8.0	6.0	2.5

[a]Refer to appendix A, figure 3.

APPENDIX C

DATA FROM COMPARATIVE FIELD MEASUREMENTS

Table 4. Cooperative State-Federal study results of leakage tests as functions of water load, volume, and placement

Oven No.	Maximum leakage (mW/cm^2) with door closed					
	275-ml water load	50-ml water load				
	centered	centered 3[a]	1[a]	2[a]	4[a]	5[a]
4B	125	110	200	80	110	75
28A	45	30	40	45	35	90
11A	40	50	40	50	50	60
42B	40	80	150	70	130	150
34B	30	50	70	100	60	40
8B	25	50	60	20	30	50
21B	25	50	40	30	25	20
20A	25	70	25	130	60	100
22A	25	35	60	30	90	35
10A	20	20	20	20	25	40
43A	20	200	200	200	200	200
5B	20	30	09.0	20	20	30
7B	20	70	60	20	50	70
22B	15.0	50	60	90	60	50
27B	15.0	5.0	8.0	20	7.0	5.0
14A	10.0	25	4.0	4.0	4.0	15.0
21A	10.0	12.0	15.0	8.0	20	6.0
30A	10.0	10.0	5.0	5.0	6.0	20
32B	10.0	20	6.0	7.0	18.0	25
35B	10.0	30	20	35	40	25
44A	8.0	15.0	30	10.0	10.0	5.0
12A	5.0	9.0	20	10.0	10.0	15.0
13A	4.0	20	20	10.0	5.0	4.0
19A	4.0	10.0	10.0	4.0	3.0	8.0
11B	4.0	5.0	10.0	20	17.0	4.0
27A	3.0	20	10.0	20	25	20
10B	3.0	3.0	8.0	11.0	17.0	12.0
12B	3.0	20	5.0	2.0	5.0	5.0
14B	3.0	3.0	6.0	3.0	5.0	8.0
17B	3.0	5.0	20	20	18.0	20
31B	3.0	17.0	20	10.0	11.0	4.0
40A	2.0	3.0	4.0	2.0	3.0	2.0
3B	2.0	1.5	3.0	5.0	7.0	4.0
15B	2.0	0.9	3.0	2.0	0.9	2.0
25B	2.0	5.0	5.0	7.0	5.0	3.0
29B	2.0	2.0	2.0	1.0	1.0	2.0
30B	2.0	2.0	2.0	2.0	2.0	2.0

[a]Numbers refer to load positions, refer to appendix A, figure 3.

Table 4. Cooperative State-Federal study results of leakage tests as functions of water load, volume, and placement (continued)

Oven No.	Maximum leakage (mW/cm^2) with door closed					
	275-ml water load	50-ml water load				
	centered	centered 3[a]	1[a]	2[a]	4[a]	5[a]
5A	1.5	2.0	1.5	1.5	2.0	4.0
6B	1.5	0.8	3.0	1.4	1.7	2.0
24B	1.0	1.0	1.0	1.0	3.0	1.0
26B	1.0	2.0	3.0	3.0	2.0	2.0
28B	1.0	7.0	4.0	2.0	5.0	5.0
6A	0.9	0.0	3.0	8.0	25	30
8A	0.5	1.4	1.6	4.0	2.0	2.0
9B	0.5	2.0	1.5	1.0	1.5	1.0
13B	0.5	1.0	1.0	3.0	2.0	1.0
16B	0.5	2.0	1.0	1.5	2.0	1.5
23B	0.5	2.0	1.0	1.0	0.5	0.5
24A	0.4	0.2	1.5	0.1	0.5	0.7
2B	0.4	0.5	0.0	0.2	0.9	0.1
1B	0.2	0.4	0.1	0.4	0.8	0.2
1A	0.03	0.02	0.01	0.04	0.02	0.01
7A	0.0	1.0	1.5	2.0	0.0	1.3
18B	0.0	2.5	2.5	2.0	2.5	6.0
19B	0.0	2.0	10.0	3.0	10.0	7.0
20B	0.0	1.0	2.0	3.0	1.5	0.5
37B	0	0	0	0	0	0
38B	0	0	0	0	0	0
39B	0	0	0	0	0	0
40B	0	0	0	0	0	0
41B	0	0	0	0	0	0
42B	0	0	0	0	0	0

[a]Numbers refer to load positions, refer to appendix A, figure 3.

APPENDIX D

DATA FROM LABORATORY MEASUREMENTS

Table 5. Microwave leakage in mW/cm^2 with different volumes of water in five positions within three microwave ovens tested in the laboratory

Oven	Position of food[a]	Water load volume (ml)											
		50	100	150	200	250	275	300	350	400	450	500	550
General Electric	1	7.0	1.0	3.0	0.9	0.1	-	0.2	0.2	0.4	0.3	0.2	0.3
	2	1.5	1.7	1.3	1.3	1.3	-	0.9	0.8	0.8	0.7	0.8	5.0
	3	3.0	1.0	2.5	2.3	4.0	-	1.0	2.0	1.5	1.4	1.4	1.5
Magic Chef	1	20	3.0	5.9	5.2	6.0	8.5	5.2	4.5	4.3	3.0	2.0	4.5
	2	3.5	3.5	8.0	1.0	1.7	2.5	2.7	1.7	2.0	2.0	1.0	1.5
	3	8.5	5.0	6.0	4.0	5.0	4.0	4.0	2.9	4.0	2.0	2.8	3.5
	4	6.7	7.0	9.9	3.5	2.7	3.0	3.1	2.5	2.3	1.0	1.8	0.9
	5	6.2	4.5	3.0	1.2	2.0	1.7	2.7	2.5	3.7	2.6	2.2	3.0
Garland	1	0.07	0.08	0.06	0.08	0.05	0.05	0.02	0.02	0.02	0.01	0.01	0.01
	2	0.10	0.05	0.05	0.03	0.03	-	0.02	0.03	0.02	0.03	0.03	0.04
	3	0.14	0.20	0.30	0.40	0.30	-	0.20	0.30	0.20	0.18	0.11	0.09
	4	0.10	0.12	0.09	0.03	0.03	-	0.02	0.02	0.03	0.02	0.01	0.01
	5	0.05	0.09	0.06	0.05	0.03	-	0.05	0.07	0.07	0.06	0.06	0.04

[a]Refer to appendix A, figure 3.

Table 6. Microwave leakage in mW/cm^2 with different volumes of water in five positions within six microwave ovens tested in the laboratory under condition of a deliberately-produced leakage

Oven	Position of load[a]	Water load volume (ml)											
		50	100	150	200	250	275	300	350	400	450	500	550
General Electric	1	35	20	22	14	9.5	9.5	6.5	4.0	4.0	3.5	3.6	2.0
	2	40	30	22	22	15	30	17	7.5	10.0	8.0	11	12
	3	35	25	45	40	40	35	32	45	45	40	40	30
Magic Chef	1	75	17	9.8	7.5	8.5	9.2	10.5	8.5	7.0	7.5	5.9	7.5
	2	28	14.8	16.0	3.5	16.8	9.5	7.0	17.5	7.3	8.5	7.3	10.8
	3	40	10	12.3	8.8	11.8	9.5	17.3	7.3	12.8	10.2	16.0	19.0
	4	32	15.2	19.0	6.5	9.0	9.8	7.2	8.0	8.2	12.0	5.0	9.0
	5	23	17.8	25	14.0	19.8	17.0	11.3	18.5	11.8	16.2	17.2	25
Garland	1	7.5	14	9.5	11.3	7.0	6.5	8.5	5.8	6.2	5.5	4.1	3.8
	2	13.2	20	11.5	11.3	8.2	8.0	5.0	5.2	4.0	2.9	2.8	3.3
	3	7.8	6.1	7.2	8.0	6.1	10.5	10.3	9.2	8.5	6.5	6.5	7.0
	4	9.8	7.5	6.2	3.2	4.0	3.8	4.0	5.8	8.7	8.6	8.2	7.0
	5	8.5	8.0	6.0	5.0	5.0	5.1	3.3	3.7	3.5	4.2	4.5	2.5
Amana RR-2	1	10.0	10.0	8.0	8.0	8.0	6.5	7.5	9.0	6.0	4.0	2.5	2.5
	2	8.5	9.5	8.5	10.0	10.0	7.0	9.5	8.0	6.5	7.5	9.0	8.5
	3	18	16.5	15.5	13.5	10.5	11.5	11.5	15.0	11.5	8.5	5.5	5.0
	4	6.5	10.0	11.5	8.0	8.5	8.0	7.0	7.5	8.5	8.0	7.5	4.5
	5	9.5	10.0	7.5	7.5	6.5	8.0	8.5	5.5	4.5	4.0	4.0	3.5
Omnivend	1	25	31	30	15.5	12.5	7.5	8.5	21	16	12.8	11	13.5
	2	55	30	27	9.2	17	22	17	21	8.0	10.5	4.5	3.2
	3	8.0	38	5.5	5.0	11.0	10.5	12.0	7.5	14.5	14.0	10.0	4.1
	4	11.0	7.2	4.5	11.5	2.2	5.5	5.5	6.5	6.3	4.5	3.8	3.8
	5	14.0	9.0	15.0	8.1	4.3	3.2	4.2	3.0	3.9	3.0	4.3	3.5
Litton 800	1	6.5	3.0	8.0	8.0	6.0	8.0	6.0	7.0	10	10	6.0	7.0
	2	9.0	7.0	8.0	8.0	4.0	8.5	8.0	9.0	10	9.0	10	11
	3	7.0	9.0	6.0	11	12	10	8.5	6.5	8.0	7.0	7.0	8.0
	4	6.0	7.5	7.0	8.0	7.0	3.0	4.0	3.0	2.0	3.0	3.0	2.0
	5	3.0	6.5	5.0	8.5	7.0	9.0	8.0	6.0	3.0	3.0	2.0	10.5

[a]Refer to appendix A, figure 3.

Table 7. Variation of microwave leakage with changes in position of specific foods under condition of deliberately-produced leakage

Oven	Position of load[a]	Microwave leakage (mW/cm^2)					
		Creamed peas (380g)	Medium size potato (158g)	Hamburger (71.5g)	Fishcake (58g)	Hamburger bun (40g)	Caramel nut roll (30g)
General Electric	1	3.5	8.0	14.0	15.0	15.0	12.0
	2	5.5	6.0	15.0	16.0	12.5	17.0
	3	11.0	15.0	11.5	13.5	12.0	13.5
Magic Chef	1	5.0	8.0	19.5	22	13.5	8.0
	2	4.0	6.0	12.0	7.0	7.8	11.5
	3	6.0	12.5	12.5	17.5	35	7.5
	4	6.0	8.0	11.5	10.5	7.0	6.0
	5	12.0	8.5	17.5	19.0	11.5	11.5
Garland	1	5.0	9.0	8.5	12.5	7.0	7.0
	2	3.0	11.0	5.5	11.0	9.0	20
	3	4.0	11.5	5.5	6.0	4.5	8.0
	4	2.0	9.0	6.0	7.0	6.0	10.0
	5	2.0	6.0	6.5	9.5	6.0	12.0
Amana	1	5.0	5.0	7.5	9.0	9.0	10.0
	2	4.0	6.0	6.0	7.5	9.0	15.0
	3	4.0	8.0	14.0	12.0	10.0	19.5
	4	5.5	7.0	7.0	11.2	7.0	8.5
	5	2.5	7.0	10.0	11.5	9.0	13.5
Omnivend	1			7.5	12.5	18.0	20
	2			7.0	8.0	13.0	11.5
	3			9.0	16.0	6.0	5.0
	4			13.0	10.0	9.0	11.0
	5			2.0	7.0	7.0	6.0
Litton 800	1	5.0	6.0	4.0	5.5	6.0	7.0
	2	4.0	3.0	5.0	4.0	5.0	10.0
	3	4.0	4.0	6.0	7.5	5.0	6.0
	4	2.5	3.0	7.0	4.5	5.0	7.0
	5	3.0	8.0	5.5	7.0	5.0	8.0

[a]Refer to appendix A, figure 3.

APPENDIX E

DATA FROM MISCELLANEOUS TESTS

Instrumentation: Narda 8100 Meter S/N #2003

Meter Response: Fast position

Measurement Position: Maximum along edge of door at 5 cm

Test Oven: Solid lines - Amana RR-2
Open lines - Omnivend

Condition of Test: Deliberately produce test condition for easy detection of levels; w = water, c.o. = corn oil, 275 ml each

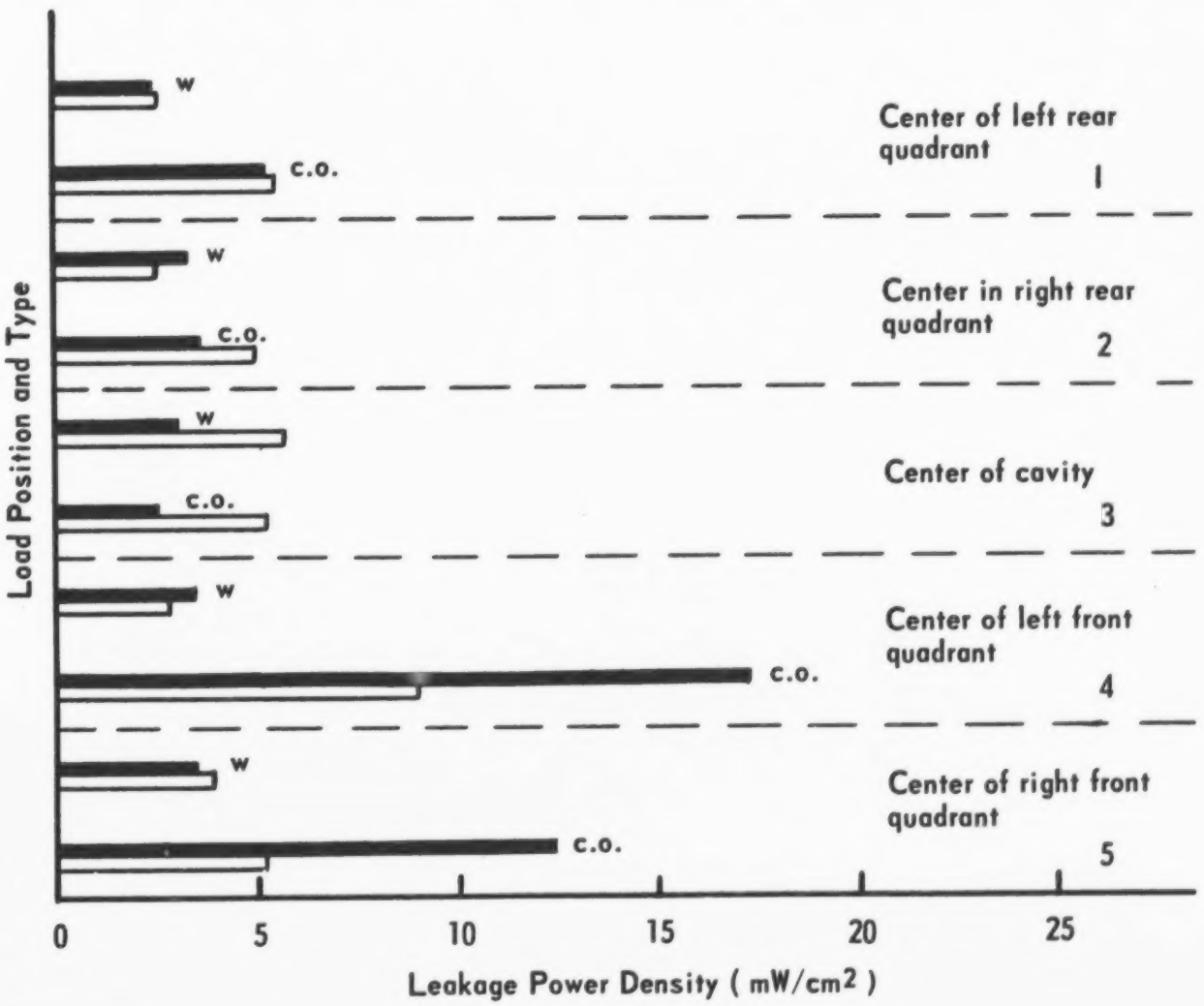

Figure 5. Microwave leakage as a function of type of test load and position with a deliberately-produced leak.

Table 8. Leakage during door opening with different interlock adjustments

Instrumentation: Narda 8110 meter S/N 1023
Probe 8122 S/N 2005

Meter response: Fast position

Measurement position: At edge of door

Oven: Tappan model R4A,
S/N 04190-1828-2590

Position of interlock switch	Door opening leakage Power density - mW/cm^2
Extreme position	Oven would not operate with door completely shut
Position that allows oven to operate with minimum door opening	75
Intermediate position	130
Maximum adjustment	200 (at 3-inches from oven seal)